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WFC3
CONTAMINATION CONTROL
IMPLEMENTATION PLAN

November 2000

REVIEW COPY

Goddard Space Flight Center
Greenbelt, Maryland

WIDE FIELD CAMERA 3 (WFC3)
CONTAMINATION CONTROL AND IMPLEMENTATION PLAN (CCIP)

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1.0 INTRODUCTION

1.2 PURPOSE

This document details the contamination controls and monitoring methods, which will be implemented to ensure that the Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3) will be delivered to orbit in a condition meeting the contamination requirements specified in STR-29, "Hubble Space Telescope Servicing Mission Contamination Control Requirements." This document also addresses the internal requirements specific to the instrument, while undergoing manufacturing, assembly, integration, test and crew familiarization activities at Swales Aerospace (SWALES), Ball Aerospace (BALL), Goddard Space Flight Center (GSFC), and Kennedy Space Center (KSC).

1.2 SCOPE

This document specifies the implementation of the WFC3 cleanliness requirements from manufacturing through launch. Where a conflict exists between this document and another contamination control plan, the more stringent requirements must be followed. Work performed at BALL must comply with this document and with BALL Systems Engineering Report WFC3-SYS-010, “Wide Field Camera 3 Contamination Control Plan.”

The facility / test specific sections of this document are intended to be copied into the respective test plans or procedures. The sequence in which the testing is performed does not affect the contamination controls. All work orders or procedures, which transport WFC3 hardware between clean areas should incorporate the controls specified in the transportation section of this document.

2.0 APPLICABLE DOCUMENTS

BPS 21.04	Contamination Control, Clean Rooms, and Clean Benches
FED-STD 209	Cleanroom and Work Station Requirements, Controlled Environment
MIL-STD 1246	Product Cleanliness Levels and Contamination Control Program
JSC-SN-C-0005	Contamination Control Requirements for the Space Shuttle Program
NSI 35-01-203	SSDIF Cleanroom Operating Procedure
NSI 35-01-205	Routine Cleaning of the SSDIF Cleanroom
P-442-1466	Science Instrument Purge Cart Operating Procedure
STR 29	HST Contamination Control Requirements
WFC3-SYS-010	Ball Systems Engineering Report: WFC3 Contamination Control Plan

3.0 CONTAMINATION REQUIREMENTS

3.1 HST IMPOSED REQUIREMENTS

These requirements are imposed by STR 29, “HST Contamination Control Requirements”.

3.1.1 Internal to the Aft Shroud

The exterior surfaces of the hardware must meet Level 400B per MIL-STD-1246. When held 10 ^{o}C above their on-orbit maximum predicted temperature, the components must outgas no more than 1.56×10^{-9} g/cm^{2}/hr of materials condensible at -20 ^{o}C. Aft Shroud hardware may be exposed only in class 10,000 cleanroom environments. The WFC3 instrument will be internal to the Aft Shroud.

3.1.2 External to the Aft Shroud

Hardware which is external to the Aft Shroud must meet Visibly Clean Highly Sensitive per JSC-SN-C-0005, and have an outgassing rate which does not degrade the thermal performance of the HST Multi Layer Insulation (MLI) or Aft Shroud surfaces. Non-Aft Shroud hardware may be exposed in class 100,000 or better cleanroom environments. The painted surface of the WFC3 radiator is exposed outside the Aft Shroud; however, it shall be treated in the same manner as hardware which is internal to the Aft Shroud.

3.1.3 Ground Support Equipment

Ground Support Equipment (GSE) which comes in contact with HST flight hardware must be cleaned to the surface cleanliness of that hardware. GSE which will be used in a vacuum chamber must be baked out to a rate which will not contaminate the flight hardware; this rate must be determined by molecular transport analysis for each test configuration. GSE used in a cleanroom but not in contact with flight hardware shall be cleaned to Visibly Clean Highly Sensitive, with less than 2 mg/ft2 of NVR.

3.2 WFC3-IMPOSED REQUIREMENTS

The WFC3 contains contamination sensitive detectors and optics. These contamination sensitive components are contained inside the optical bench (OB) cavity and are isolated from the electronics boxes, which are mounted in the space between the OB exterior and the instrument enclosure. There are two optics performance goals that are influenced by contamination. They are polarization and throughput degradation. Table 3-1 defines these goals.

TABLE 3-1 : CONTAMINATION PERFORMANCE GOALS

OPTICAL
Polarization: UVIS (200 < λ < 1000 nm): < 6.5% IR (850 < λ < 1750 nm): < 5%
SPECTRAL
Throughput Degradation: UVIS (200 < λ < 400 nm): < 6% per surface at EOL (5 years) IR: < 1% per surface at EOL (5 years)

The surfaces most sensitive to contamination are the WFC3 optics. The loss on these surfaces occurs due to obscuration caused by settled particle and photon absorption in the NVR deposits. The contamination budgets will be driven by the losses in the UVIS channel at 200 nm because the absorption coefficient is larger in the UV than in the IR.

3.2.1 Internal Surface Cleanliness

Flight hardware for WFC3 must be Level 400A/2 to keep the optic surface obscuration at less than 0.1%. The optical bench and all hardware in the optical cavity, however, must have a surface NVR level of 0.2 mg/ft^2 at beginning of life and 0.5 mg/ft^2 at end of life. The optical bench must have an outgassing rate as described in 3.2.2. NVR on optics must be less than 15 ng/cm^2 (15 Angstroms) at launch and less than 30 ng/cm^2 (30 Angstroms)and produce less than 6% degradation of throughput at end of life.

3.2.2 Component Outgassing Rates

Non-metallic hardware must be baked at the maximum allowable temperature up to 125 ^{o}C until the outgassing rate is less than 4.33×10^{-13} g/cm^2 -s of material condensible at –20 ^{o}C. Parts similar to those of previous BALL programs may be baked out using a time-temperature combination which has been shown to produce the desired outgassing rate.

Components internal to the Optical Bench, and the bench itself, must be certified at +30 ^{o}C. To minimize thermally induced movement, the optical bench bakeout is limited to 60 ^{o}C. The collection temperature shall be –40 ^{o}C, and the total outgassing from the bench and optical components must be less than 3×10^{-9} g/s (this number will be updated as the WFC3 model is refined). This rate will assure that the Refractive Corrector Plate, which operates at –40 ^{o}C, will collect no more than 300 Angstroms of deposition by the end of life.

Other hardware must be certified at 10 ^{o}C above the maximum predicted operating temperature. Where practical, QCM data must be taken with the QCM at –40 ^{o}C and the hardware at +15 ^{o}C and 0 ^{o}C. This data will be used in the WFC3 contamination model.

3.3 CONTAMINATION BUDGET

The nature of spacecraft manufacture, assembly, and integration is such that parts are easier to clean at lower levels of assembly, and parts are more likely to require operations outside of a cleanroom at low levels of assembly. Although cleaning occurs whenever a part is integrated into a higher levelassembly, contamination will accumulate in the areas which become inaccessible. This accumulation will be monitored by witness plates. If the levels specified in figures 3-1 and 3-2 are exceeded, cleaning must be performed. The optical requirements driving these contamination levels are as follows:

UVIS: $200<\lambda<400$ loss < 0.02 per surface at delivery to GSFC

loss < 0.03 per surface at delivery to KSC

loss < 0.04 per surface at launch
loss < 0.06 per surface at EOL (5 yrs)

IR : $1000<\lambda<1600$ loss < 0.004 per surface at delivery to GSFC
loss < 0.006 per surface at delivery to KSC
loss < 0.007 per surface at launch
loss < 0.01 per surface at EOL (5 yrs)

Optical degradation budgets for the individual optics are specified in the BALL Systems Engineering Report WFC3-SYS-10, “Wide Field Camera 3 Contamination Control Plan”.

Figure 3-1: NVR Contamination Budgets

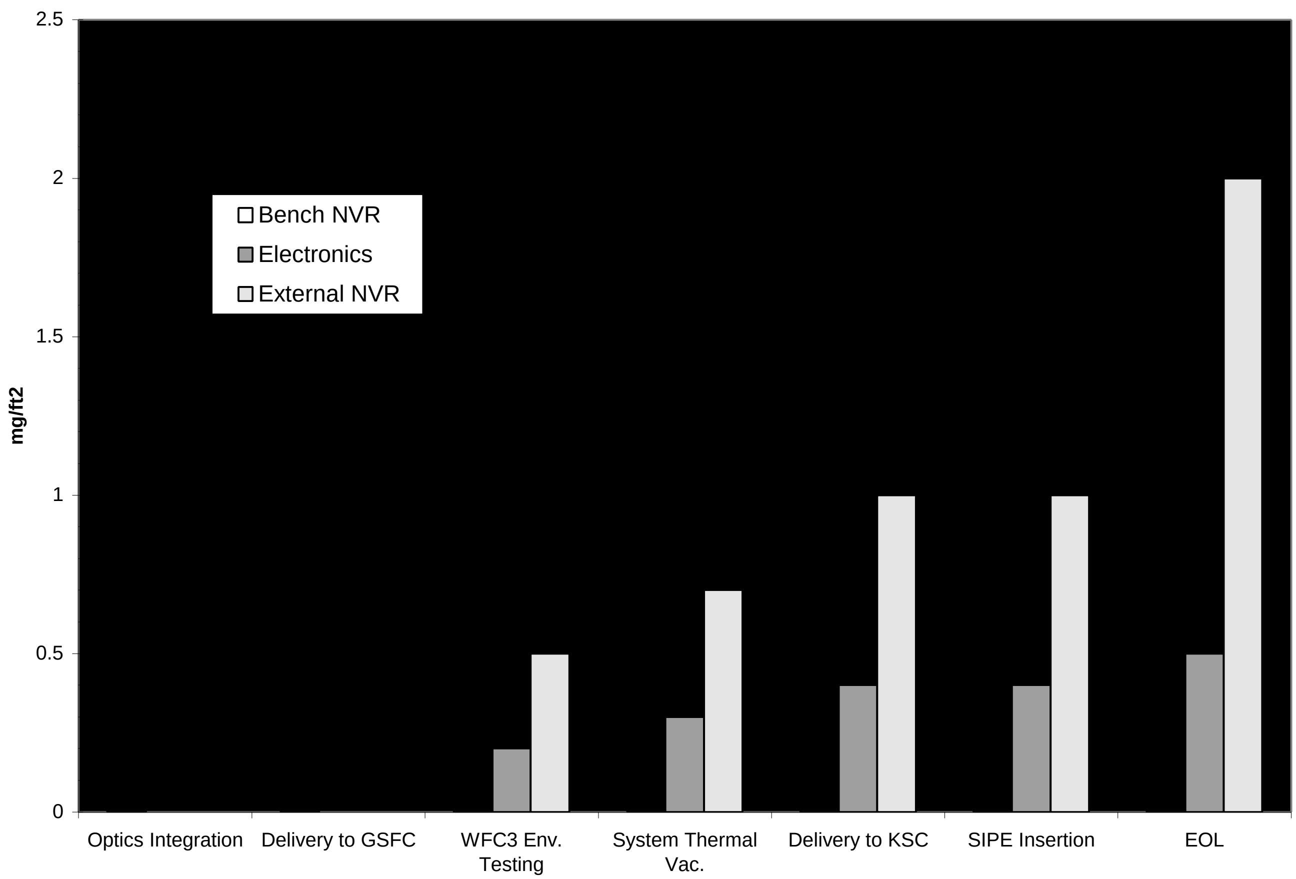
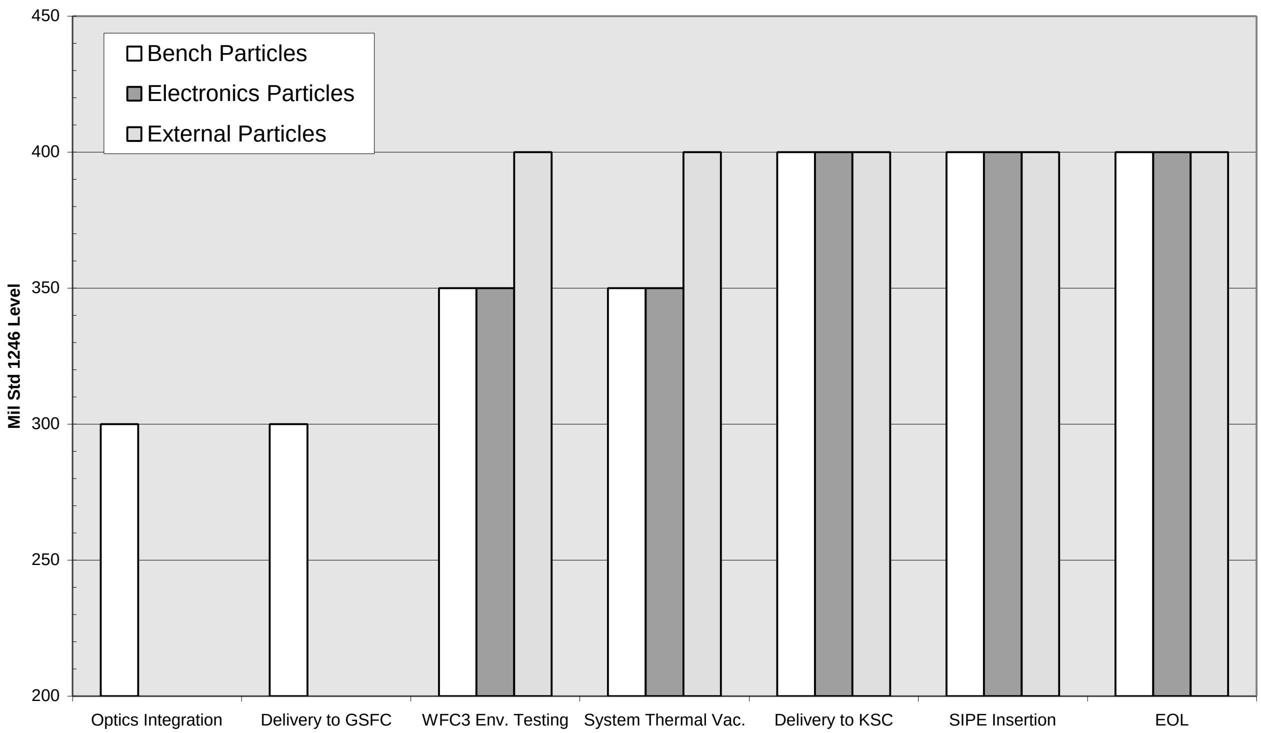


Figure 3-2: Particle Contamination Budgets



4.0 IMPLEMENTATION

4.1 HARDWARE SPECIFIC CONTROLS

4.1.1 Instrument shell/enclosure

The Wide Field Planetary Camera 1 (WF/PC-1) enclosure must be re-used to the extent possible. This structure must be processed in a class 100,000 or better clean area during de-integration of the WF/PC-1 components. Prior to WFC3 assembly, the enclosure must be cleaned and verified to an NVR level of 0.2 mg/ft^2 and a particulate level of 400 in accordance with MIL-STD-1246. Composite piece parts must be cleaned using solvents or detergents approved by GSFC. Once clean, this structure must be processed in a class 10,000 cleanroom.

4.1.2 Optical Bench

The optical bench (OB) must be cleaned and verified to an NVR level of 0.2 mg/ft^2 and a particulate level of 300 in accordance with MIL-STD-1246. After integration, the optical bench must be maintained at level 400 A/5 or better.

Composite sheets must be cleaned using the following solvent sequence: Acetone, Simple Green, IPA. These parts shall be cleaned until a water-break test indicates that surfaces are free of contaminants and then be covered and dried in an oven. Parts shall be covered when not being worked on. After consolidation into honeycomb panels, the parts shall not be exposed except in a class 100,000 or better environment. Cleaning of honeycomb panels will use IPA, taking care not to allow solvents into the honeycomb through vent openings.

Representative composite samples (approximately 2x2 inches) must accompany the hardware through all processing. Samples consisting of both face sheet and honeycomb structure must be used.

Inserts must be provided on the OB to support optical witness mirror sample mounts. The OB must be vacuum baked and the OGR TQCM certified to par. 3.2.2. After vacuum bakeout, the OB must be bagged and purged to the greatest extent possible.

4.1.3 Electronics

Only approved materials must be used in the electronics boxes. The box shells must be cleaned to Level 400A/2 before installation of the cards. After card installation, the electronics boxes must be individually baked out at the maximum allowable temperature until they reach the requirements of Section 3.2.2. The external surfaces of the boxes must be maintained at Level 400A/2.

Cables must be layed up in a clean environment using nitrile or lates gloves. After assembly, cables must be cleaned to Level 400 A/5 and vacuum baked to the requirements of par. 3.2.2.

Connectors must be precision cleaned or inspected with a 10x magnification to verify the absence of particles. Connector inserts shall be vacuum oven baked in accordance with GSFC or Ball recommendations.

If an electronics box is to be tested outside a class 10,000 cleanroom following bakeout, the vent holes and connectors must be covered, and surface recleaning to Level 400A/2 is required.

4.1.4 Radiator

The WF/PC-1 radiator will be stripped and recoated. Prior to recoating, the radiator must be cleaned to Level 300A. Once the radiator is coated with silicate paint, the painted surface must be considered a no-touch area. This surface must be draped with bagging material whenever possible. The coated radiator must be double bagged when not in a class 10,000 clean area. Heat pipes must be cleaned to Level 400A before integration with the radiator. The non-coated portions of the radiator/heat pipes must be cleaned and verified to an NVR level of 0.5 mg/square foot and a particulate level of 400 before integration with the rest of WFC3.

4.1.5 SOFA/Shutter Assembly

The WF/PC-1 SOFA mechanism must be refurbished for use in WFC3. The component parts must be precision cleaned to Level 400 A/5. Only baked out Braycote 601 or 602 or dry lubes shall be used as a lubricant for the motor and mechanisms. The OGR must be certified to the requirements of par. 3.2.2 before delivery and integration into the OB.

4.1.6 IR Filter Wheel Mechanism

The IR filter wheel mechanism motor must be lubricated with baked out Braycote. The component parts must be precision cleaned to Level 400 A/5 and baked out at their maximum temperature until they meet the outgassing requirements of section 3.2.2.

4.1.7 M1 Tip/Tilt Mechanism

The M1 tip/tilt mechanism motor must be lubricated with baked out Braycote. The component parts must be precision cleaned to Level 400 A/5 and be baked out at their maximum temperature until they meet the outgassing requirements of section 3.2.2.

4.1.8 UVIS Detector

The UVIS detector enclosure protects the detector from contamination originating in the instrument or the instrument environment. To maintain the required vacuum levels in the detector enclosure, the enclosure must be vacuum baked for an extended period of time. Total gas load is of concern for thermal reasons, and hydrocarbon sources are of concern if outgassed species condense on the CCD. After initial conditioning, exposure to atmospheric gases will not increase the hydrocarbon outgassing rate. However, even exposure to ultrapure nitrogen will cause surface adsorption of gas and require reconditioning of the detector housing.

All surfaces internal to the detector housing shall be cleaned to Level 300 A/5 or better.

A vent tube will be used to maintain the detector vacuum on the ground, and will be open to space on orbit. This tube must be capable of being connected to and disconnected from the GSE vacuum pump without losing the vacuum. For EVA purposes, no trapped pockets of gas are allowed in the plumbing. Vent tube diameter shall be maximized within the stiffness constraints imposed by the load and vibration limits on the detector housing. The bakeout required to reduce the outgassing to an acceptable level will be determined after the vent tube design is finalized, as the conductance of the tube will be a significant factor.

4.1.9 UVIS Calibration Lamp

The design of the UVIS calibration system is intended to prevent contamination of the calibration lamp(s). To prevent externally induced degradation of the WFC3 cal lamp, molecular adsorbers may be required in the vicinity of the lamp. Testing and analysis of the calibration system must be performed to validate the cleaning and assembly process, and to determine whether or not adsorbers are required. If required, the adsorber units must be replaced after thermal vacuum testing.

4.1.10 IR Detector

The detector enclosure is completely inside the “cold enclosure” which runs at 233K on-orbit, while the HgCdTe focal plane runs at 150K. Because of the packaging geometry of the “cold enclosure”, the only surface that runs a high risk of collecting contaminants during operation on-orbit is the outer surface of the Refractive Corrector Plate. The IR detector housing has a vent tube and is subject to the same controls as the UVIS detector housing (Section 4.1.8).

4.1.11 RIAF

The Radial Instrument Alignment Fixture (RIAF) has been used for the optical verification of WF/PC-1 and WF/PC-2. The fixture consists of a framework with instrument latches, and a tube containing a light source and optical elements to generate a light beam with the same focus and aberation characteristics as the Hubble Space Telescope. The pickoff mirror of the WFC3 will be inserted into an opening in this tube. Because WF/PC-1 had an aperture window, contamination sources within the RIAF were not considered a problem. WF/PC-2, which did not have any windows between the pickoff mirror and a detector running at –70 C, developed an insert for the RIAF tube to block contamination from the fixture.

Prior to use, the RIAF shall be baked out and certified in a vacuum chamber by placing a QCM in the tube where the pickoff mirror will be. If necessary, the contamination blocking insert will be used. The temperatures of the insert and the RIAF tube will be adjusted until an acceptable molecular flux is measured with the QCM at –40 C. The required flux is TBD, based on modelling of the WFC3 thermal vacuum set-up.

4.2 MANUFACTURING

4.2.1 Machine Shop

Most of the hardware manufacturing will take place in areas exceeding a level 300,000 cleanliness specification (FED-STD 209D). During manufacturing, the following handling requirements must be followed:

1. During contamination generating operations such as drilling, welding, etc., contaminants (metal chips, dust, and so forth) must be vacuumed off the hardware as they are generated.

2. Lubricant deposits (grease/oil) must be cleaned off immediately by using a clean wipe dampened with an alcohol solvent.

3. When appropriate (drilling, cutting), alcohol must be used as a cooling agent / lubricant.

4. Prior to applying coatings or paints, surfaces must be cleaned and visually inspected as per the coating application procedures.

5. All areas which become inaccessible during the fabrication and assembly process must be thoroughly cleaned using a solvent and then inspected by QA to Visibly Clean, Sensitive prior to becoming inaccessible. Areas which cannot be cleaned must be sealed (e.g., placing flight approved tape over a crevice) to prevent later contamination of nearby surfaces.

6. After manufacture is complete, the part must be wiped, blown with filtered, oil-free air, or vacuumed free of debris. Parts smaller than 12 inches in diameter must be placed in a polyethylene, RCAS 4200, Lumalloy, or other approved bag for handling. Larger parts must be wrapped with bagging material; if required, cut-outs may be made for lifting points.

Work performed at BALL must comply with BALL Systems Engineering Report WFC3-SYS-010, “Wide Field Camera 3 Contamination Control Plan.”

4.2.2 Harness/Cable Manufacture

The cables used in WFC3, or in a vacuum chamber with WFC3, must be assembled from pre-cleaned Teflon coated wire that is wiped down with IPA and handled with latex gloves during the assembly process. The assembly must be performed on a table which is maintained free of grease, oil, flux, or other contaminating residues. The wire may be pre-baked at 80-125 ^{o}C for schedule purposes. Connector inserts and grommets, unless delivered pre-baked by the vendor, must be pre-baked in accordance with GSFC code 541 (Materials Engineering Branch) guidelines, typically a 150 - 200 ^{o}C vacuum oven bake for 24 - 48 hours. After assembly, the harnesses must be baked out and certified to meet the requirements listed in Section 3. After bakeout, the harnesses must be double bagged when not in a class 10,000 cleanroom.

4.2.3 Motors and Gear Assemblies

Many of the motor and gear assemblies will be provided by vendors without adequate verification facilities. Because these parts cannot be internally cleaned after assembly, the piece parts must be shipped to BALL or GSFC for cleaning and bakeout, then returned to the vendor for final assembly. Vendors must have a clean-bench for assembly. Baked out Braycote or a dry lubricant must be specified as the internal lubricant for these assemblies.

4.2.4 Clean Room Operations

Some manufacturing operations will occur within a cleanroom, and may interface with higher level assemblies. When this occurs, all hardware must be cleaned to the level of the cleanest part. During cutting, shaping, or drilling operations, a HEPA filtered vacuum must be employed to collect particles as they are generated. Potting and staking operations must minimize the amount of epoxy used; any drips or spills must be immediately cleaned and the CCE must be notified. All tools, including pens and markers, must be approved and cleaned to VCHS.

4.3 ASSEMBLY

Items must be cleaned prior to assembly. Surfaces must be free of grease/oils and crevices/holes must be vacuumed to remove chips or particles. Unless otherwise specified, flight hardware must be cleaned to Level 400 A/5. Cleanliness requirements for hardware may be found in Section 3 and Section 4.1. In most cases, assembly of subsystems will occur in a better than class 10,000 clean area. Clean area cleanliness levels must be monitored as specified in Section 6. Work performed at BALL must comply with BALL Systems Engineering Report WFC3-SYS-010, “Wide Field Camera 3 Contamination Control Plan.”

During assembly, hardware should be cleaned and inspected at regular intervals to prevent violation of the contamination budget. The cleanliness of optical components shall be measured using witness mirrors. Optical components must be cleaned by BALL or GSFC optical personnel only. The following procedure must be used for piece parts which are disassembled at the end of each building stage:

1. All surfaces, holes, perforations, and crevices must be cleaned with alcohol using clean wipes or swabs. Painted surfaces must be treated separately. Continue cleaning until surfaces appear visually clean and until no contamination is visually seen on wipes.

2. If necessary, vapor degrease the surfaces with an approved solvent. (Halogenated solvents are absorbed by plastics and later leached out or outgassed. Therefore, if plastics are to be vapor degreased, a bakeout must be required.)

3. Inspect visually with white light.

4. Record the results in a certification log or equivalent.

The following procedure must be performed prior to the final assembly:

1. Vacuum the entire surface of the previous assembly, giving special attention to crevices, riveting surfaces and holes, and anywhere particulate contamination might be lodged.

2. Using dry nitrogen, blow all crevices and riveting surfaces. Vacuum off any particulate matter that may remain.

3. Wipe surfaces with alcohol.

4. If necessary, vapor degrease these surfaces using an approved solvent.

The following procedure must be used during and after assembly:

1. Wipe surfaces as contamination is generated (riveting, etc.).

2. Inspect surfaces for accumulated contamination. Clean as required.

3. Clean all surfaces of generated contamination after assembly is complete. Follow the same cleaning procedures as followed prior to assembly.

4. Inspect and record the results in a certification log or equivalent.

4.3.1 Electronics Boxes

The Remote Interface Unit (RIU) is GFE and will be provided clean by GSFC. The other electronics boxes will be assembled in accordance with GSFC standard practices for assembly of electronic components. After the cards are assembled and conformal coated, they must be vacuum cleaned and installed into their boxes. The populated electronic boxes will be baked out at 80 ^{o}C or their maximum allowable temperature prior to integration into the WFC3. The outgassing requirements are specified in Sections 3.1.1 and 3.2.2.

4.3.2 Optical Bench

Assembly of the optical bench must occur in a class 10,000 cleanroom. The optical bench, and its composite witness coupons, must be baked out prior to integration into the WFC3. The outgassing requirements are specified in Sections 3.1.1 and 3.2.2. After bakeout, the bench and coupons must be bagged and purged.

4.4 INTEGRATION

The WFC3 must be integrated in a class 10,000 cleanroom. Cleanroom monitoring will include air particle counts, particle fallout rate, NVR accumulation rate, and volatile hydrocarbon monitoring. If any cleanroom requirements are exceeded, the WFC3 must be bagged, and work must not resume until the cleanroom is returned to a clean state. Work performed at BALL must comply with BALL Systems Engineering Report WFC3-SYS-010, “Wide Field Camera 3 Contamination Control Plan.”

The WFC3 radiator surface is a silicate paint. Due to the rough surface, cleaning is difficult. When operations permit, WFC3 must be draped with bagging material. When cleaning is required, this surface must be vacuumed by trained personnel only.

Unless actively being worked upon during the integration and testing phase, the WFC3 must be purged with nitrogen to prevent particulate contamination of the interior and to control moisture absorption by the graphite honeycomb structure, dry lubricants, and the graphite IR cold enclosure. Optical witness mirrors must be used to monitor NVR accumulation within the instrument. The WFC3 must be double bagged when not in a class 10,000 environment.

Any materials which must be added to WFC3 after Thermal Vacuum (TV) testing must be baked out or be approved by both the BALL CCE and the HST CCE.

4.5 PURGE

4.5.1 Flow Rate

The WFC3 must be purged with 6-10 ft^3/hr of grade B Nitrogen (GN_2) per MIL-P27401 (see table 4-1) by an HST purge cart. Once WFC3 has completed its last TV test, this may be disrupted for a period no longer than 1 cumulative hour in a 24-hour period. The purge must be monitored to verify flow once per covered shift if an autodialer notification system is not in use.

4.5.2 Certification

The gas supply must be certified to be Grade B nitrogen. This certification must be performed at the house supply outlet or as an “out of the bottle” certification for bottles. All purge lines and fittings must be flushed with solvent, dried, and verified to meet level 300A internally and Visibly Clean Highly Sensitive externally. Only Teflon and stainless steel lines must be used downstream of a purge cart.

4.5.3 Maintenance

A purge cart and gas supply are considered a certified purge system when the gas source has been tested to meet the purge gas requirements at both the inlet to the purge cart and at the verification point on the purge cart outlet line, and the purge hardware (inlet and outlet hoses, connectors, valves, etc.) meets the internal surface cleanliness requirements specified in section 4.5.2.

After a purge system meets these requirements, the extent to which it needs to be retested depends on subsequent modifications. Changes not requiring system level retest are replacement of lines and fittings with certified hardware, change over from one certified gas supply to another, and discontinuing the flow through a line for less then one hour (unless the line is capped). Changes must be performed in accordance with the Science Instrument Purge Cart Operating Procedure, P-442-1466.

The purge and purge cart must be maintained (monitored, changed over to different sources and tested for grade B) by code 540 while at GSFC or KSC facilities. The purge and purge cart must be maintained by BALL personnel while at BALL facilities.

4.6 INSPECTION AND MONITORING METHODS

The following inspection and monitoring methods may be used.

Table 4-1: Inspection and Monitoring Methods

Air Particle Counts	Air particle counts are a measure of the amount and size distribution of particles in a given volume of air. This is measured with an air particle counter which pulls air from the environment, separates particles based on size groups, and counts the number of particles in that size group per volume of air, typically one cubic foot. FED-STD 209 provides standard cleanroom specifications partly based on the amounts and sizes of particles present in the air supplied to a cleanroom. For the WFC3 integration and testing, particle counts will be used to verify that the environments to which the instrument is exposed are always Class 10,000 cleanrooms (or better).
Cold Finger	Cold fingers are used in vacuum tests to provide information about the molecular environment of the vacuum chamber at the end of the test. This is a cylinder of known surface area that is flooded with LN_2 at the end of a test. When flooded the cylinder resides at ~80 K and collects any molecules that hit the cylinder and are condensable at that temperature. When the chamber is brought back to ambient, the cold finger is rinsed with a solvent, and the residue is analyzed to determine its mass and constituents. The results from cold finger analyses are used to determine if any unexpected molecular contamination is present.
Grade B GN_2	As specified by MIL-P-27401 for Type I-Gaseous. Grade B is 99.99% pure and contains a max of 50 ppm O_2, 20 ppm Argon, 5 ppm CO_2, 5 ppm CO, 5 ppm THC (as CH_3), and 11.5 ppm H_2O
NVR Rinses	NVR rinses are used to determine the amount and constituents of NVR on any surface. For flight hardware, a standard quantity

	of IPA is rinsed over a known surface area on the hardware and the runoff collected. The rinsate is evaporated and then analyzed as described for NVR Witness Plates.
NVR Witness Plates	NVR witness plates are flat, polished plates of known surface area. They are exposed in an environment of interest (typically either hung or mounted in a stand) and provide a witness for any surface in the environment on which molecular residue could collect over a period of time. This plate is removed from the environment after a scheduled exposure interval and is rinsed with a solvent. The rinsate is collected and evaporated, and the residue (NVR) is weighed and analyzed to determine its constituents.
Particle Fallout Plates	Particle fallout plates are placed in an environment of interest for a specific time (dependent on the application) and are then examined for particle fallout. The plates used at GSFC are often Millipore 0.45 micron filters imprinted with a grid, or Silicon wafers. Before these are exposed, they are read under a microscope in order to get a “pre-exposed” particle count on the plate. After exposure these plates are examined under a microscope to determine the number of particles per in^2 in different size groups. A report is generated describing the sizes of and number of particles per in^2, as well as a MIL-STD 1246 particle cleanliness level, (50, 100, 200, 400 etc).
SAW	The Surface Acoustical Wave is a device that detects molecular accumulation on its crystal face. An acoustical wave is sent across the surface of the crystal whose amplitude and frequency change as it propagates through any foreign material. The end result is much like the TQCM data, however the wave is more sensitive to mass accumulations than the TQCM and therefore can be used in air.
Scavenger Plate	A large (1 ft^2 or greater) cryogenic plate sometimes employed in thermal vacuum tests to collect molecular contamination during

	tests. The plate is flooded with LN_2 for the duration of the test. This is rinsed at the end of the test for NVR analysis.
Tape Lifts	Tape lifts are performed as per GSFC 545-WI-8072.1.2. Tape is used to lift particles from the surface of a piece of hardware in an area of interest. A microscope is used to count the number and size of particles. A report similar to the report for particle fallout plate is generated, and a MIL-STD 1246 surface particle level is reported.
TQCM	Thermoelectric Quartz Crystal Microbalance is a device which measures the deposition rate of molecules on the face of a crystal. The crystal has a vibration frequency that changes as material is deposited; the output of the device is the difference between the frequency of the exposed crystal and the frequency of a reference crystal. The change in the frequency over time represents the deposition rate of material on the crystal.
VCHS+UV Inspection	As specified in JSC-SN-C0005. This is a subjective inspection for particles using the unaided eye at a distance of 12-18" from the surface of interest. The inspection uses 100 foot-candles of white light and a UV light. VCHS+UV is roughly equivalent to Level 400B per MIL-STD-1246.

4.7 TRANSPORTATION AND STORAGE

Unless double bagged and certified clean, all hardware must be cleaned before entering a cleanroom. Surface cleanliness requirements are listed in Section 3. Before transport of (clean) integrated hardware, items must be double bagged using HST approved material. At the clean area entrance the hardware outer bag must be removed. The hardware (in the inner bag) may then be transported into the clean area. Upon removal of the hardware from the bag, a visual inspection to determine the cleanliness condition must be performed. Recleaning and inspection will occur as necessary. Items to be stored in an unclean area must be double bagged prior to exiting the clean area.

4.7.1 Piece Parts

After manufacturing, piece parts must be single bagged for transportation. After cleaning, piece parts must be double bagged for transportation.

4.7.2 Assemblies

When being transported between clean areas, assemblies containing optics must be double bagged and purged by a purge cart. Other assemblies must be double bagged.

Some assemblies must be protected even in clean environments. The populated optical bench must be bagged and purged when operations permit. The coated radiator must be bagged when operations permit.

4.7.3 Instrument

When being transported between clean areas, the WFC3 must be double bagged and purged by a purge cart. Over night and when operations permit, WFC3 must be draped with bagging material. To ensure the cleanliness of the optics, the instrument must be purged whenever possible. After the final thermal vacuum test, a continuous purge (max 1 hour downtime per 24 hours) is required.

5.0 INTEGRATION AND TEST FACILITIES

The test facilities which will be used for the WFC3 include the High Fidelity Mechanical Simulator (HFMS), space environment test facilities, the EMI facility, the vibration facility, and the acoustic chamber. The HFMS is a mechanical replica of the HST Aft-Shroud located in the Spacecraft Systems Development and Integration Facility (SSDIF), a Class 10,000 cleanroom.

5.1 BALL FACILITIES

BALL cleanrooms must be operated in accordance with the Ball WFC3 Contamination Control Plan and Section 6 of this document. General assembly and work areas must be kept free of debris, clutter, and non-work related items.

5.1.1 Cleanroom

The BALL cleanroom designated “5 - 6” shall be used for integration and test of the WFC3 optics and mechanisms onto the OB..

5.1.1.1 Environment

The 5-6 cleanroom is a class 10,000 cleanroom and must be monitored per BPS21.04 . Studies have shown that the room maintains the following characteristics:

1. Quiescent air quality < Class 10
2. Temperature 16 < T < 27 C
3. Humidity 25 < RH < 50 %
4. NVR fallout < 0.15 mg/ft^2 per month
5. Particulate fallout < Level 350 per month

5.1.1.2 Monitoring

Besides the standard NVR and particulate fallout plates, at least 2 OWS mirrors and the SAW detector may be deployed in close proximity to the WFC3 OB during I&T.

5.2 GSFC FACILITIES

5.2.1 SSDIF Integration and Test

5.2.1.1 Environment

The Spacecraft Systems Integration and Development Facility (SSIDF) is a class 10,000 cleanroom and must be monitored per NSI 35-01-205. Studies have shown that the room maintains the following characteristics:

- NVR accumulation of approximately 0.8 mg/ft^2 in 3 months
- Particulate fallout less than Level 350/week (slightly higher near the VEST)
- Airborne hydrocarbons less than 5 ppm

If routine monitoring indicates higher levels of contamination, the HST CCE must be notified, even if the cleanroom operating limits are not exceeded. Monitoring must be performed in accordance with Table 6-1 of the WFC3 CCIP.

5.2.1.2 Handling

After arrival in the SSDIF cleanroom, the roll up door must be closed, and the room must be allowed to settle for 30 minutes prior to removal of the WFC3 inner bag. The WFC3 must be positioned as close to the HEPA filter bank as possible, and cleanroom chain must be used to designate the WFC3 control area, within which only authorized personnel are permitted. A maximum of 6 people are permitted in the WFC3 control area when WFC3 is not draped with bagging material. ESD wrist straps are required by all personnel in the control area. Tape cuff sealers are not permitted due to ESD constraints. Overnight and when operations permit, the WFC3 must be draped with Lumalloy. The WFC3 must be continuously purged using an HST purge cart. Prior to leaving the SSDIF, the WFC3 must be double bagged.

5.2.1.3 Monitoring

After unbagging in the SSDIF cleanroom, two optical witness mirrors must be deployed in the WFC3 control area. Two of the WFC3 traveling mirrors must be exchanged for new mirrors. One particle fallout plate must be placed immediately downstream of WFC3. A white light inspection must be performed to verify that WFC3 is Visibly Clean Highly Sensitive. If the optical witness mirrors which traveled with WFC3 show more than 1% degradation, the CCE may require an NVR rinse to be performed on WFC3.

The fallout plate must be exchanged and measured weekly. After bagging the WFC3 for transport to another facility, the two SSDIF mirrors must be measured.

5.2.2 HFMS

The High Fidelity Mechanical Simulator (HFMS) is a replica of the Hubble Space Telescope (HST) internal structure. The major components of the HFMS are the Main Ring Simulator (MRS), the Focal Plane Structure Simulator (FPSS), and the Aft Shroud Mockup (ASM). The HFMS is located in the SSDIF class 10,000 cleanroom.

5.2.2.1 Environment

The HFMS Interior must have a surface cleanliness level of Level 400B per MIL-STD 1246B. There are no exposed bare aluminum surfaces in the HFMS, and operations which expose bare aluminum are prohibited while the WFC3 is present. To minimize particulate contamination of the optics, the Hub area unused radial bay openings are sealed by removable inserts, and a debris shield is attached to the ASM and MRS such that the gap between the two is completely covered. A removable cover is placed over the central opening in the MRS to prevent particulate fallout into the hub area (for the purposes of optical tests, this cover must be an optical window). The doors to the ASM must be kept closed except during operations requiring access to the HFMS interior.

The surface cleanliness level requirement for the ASM external surface is Visibly Clean, Highly Sensitive (VCHS).

A control area must be established around the HFMS. Personnel entering the control area must walk on a tacky mat. A cleaning station must be placed at the perimeter entrance for recleaning of tools which are contaminated during use.

5.2.2.2 Handling

Optical test equipment, such as video cameras, must meet Level 400 if they are to be used inside the HFMS, and VCHS if they are to be used external to the HFMS. GSE which must contact the interior or the WFC3 must be cleaned to Level 400B.

During operations in which personnel are accessing the interior of the HFMS, a maximum of 5 persons must be permitted on the scaffolding immediately adjacent to the HFMS; no more than 2 persons must be inside the HFMS Aft-Shroud Mockup. If the maximum number of personnel must be temporarily increased, the CCE must be present to monitor operations. Personnel access to the area between the HFMS and the HEPA filters must be minimized because particles can be carried downstream to the HFMS.

ESD wrist straps are required by all personnel in the control area. Tape cuff sealers are not permitted due to ESD constraints. The WFC3 must be continuously purged using an HST purge cart.

These constraints apply to crew training activities as well as routine testing.

5.2.2.3 Monitoring

Prior to use with the WFC3, the HFMS interior must be inspected. As a minimum, tapelifts and solvent wash/swab analysis must be performed on the following areas: the ASM interior, equipment shelf, and the Science Instrument Support Structure (SISS).

During use, the Hub area molecular fallout must be monitored continuously by a Temperature Controlled Quartz Crystal Microbalance

(TQCM). In addition, a witness mirror must be exposed in the vicinity of the TQCM. If any HFMS interior hardware or the ASM interior is noncompliant with cleanliness requirements, WFC3 testing must cease until the hardware has been cleaned and reverified. The WFC3 must be protected as directed by the Contamination Control Engineer (CCE) during the reverification process. If the exterior of the ASM is noncompliant with cleanliness requirements it must be cleaned and reverified. Any sudden increase in TQCM frequency must be reported to the CCE immediately. At the end of each day, the HFMS interior must be inspected to Visibly Clean Highly Sensitive.

After WFC3 removal from the HFMS, the HFMS interior must be recleaned and inspected. WFC3 must be inspected to VCHS, and must be vacuumed if necessary. Because the HFMS is located in the SSDIF, and HFMS testing is of short duration, no changes to the WFC3 witness mirror monitoring are required.

5.2.3 Vacuum Chamber 290 (WFC3 Thermal Vacuum Test)

The thermal vacuum testing provides an environment to measure and verify the internal and external outgassing rate of the WFC3 instrument. Special care must be taken in order to ensure the WFC3 is not contaminated during this TV test and to ensure the outgassing measurements can be made accurately The Space Environment Simulation (SES) Chamber will be utilized. This chamber is a 27 foot diameter, 40 foot high vacuum chamber equiped with a removable top, a downflow HEPA filtered air supply, and a cleanroom entry for personnel.

5.2.3.1 Environment

The chamber 290 cleanroom and chamber must be certified as a class 10,000 environment prior to the start of the GSE/Chamber Pre-test Outgassing Certification. Then the chamber payload stand must be cleaned and verified to VCHS+UV.

5.2.3.2 Handling

Once the WFC3 is outside the 290 TV Test Facility, the WFC3 and Thermal Balance (TB) fixture must be lifted into chamber 290. When the lift is complete, the purge supply shall be switched to a cart in the chamber cleanroom. When all hardware has been installed in the chamber and the chamber lid has been closed, the outer bag must be removed from the instrument, and the chamber must be allowed to settle for one hour. The WFC3, TB fixture, and floor must be inspected and cleaned to VCHS before removing the remaining bag.

After the WFC3 is inside the chamber, the scavenger plate must be installed behind the optical stimulus, in the same location as during the pre-test outgassing certification. Then one final contamination inspection must be performed. Before the door is closed for pump down, but late in the test set-up flow, 4 TQCMs must be installed with direction from the CCE or its designee.

The fallout plates must be removed as soon as possible after chamber opening. Then the WFC3 must be double bagged and removed from the chamber. Once this is completed, TV test de-integration activities can continue without threatening the cleanliness of the WFC3.

5.2.3.3 Monitoring

During chamber/GSE pre-test certification, one silicon wafer fallout plate will be exposed on the payload cart during the bakeout. At the conclusion of the pre-test certification, this wafer will be tapelift tested to verify that particles are not being redistributed by the backfilling process.

After unbagging in the cleantent, one optical witness mirror must be deployed on the thermal balance fixture. One of the WFC3 traveling mirrors must be exchanged for a new mirror. Two particle fallout plates must be placed on the payload cart. The fallout plates must be exchanged prior to chamber door closure with silicon wafer fallout plates. These wafers will be tapelift tested after door opening at the conclusion of testing (or during any test interruptions). The witness mirror must be collected after the WFC3 is bagged at the test conclusion.

Air particle counts and volatile hydrocarbons must be measured once per shift while the WFC3 is exposed on the payload cart. The floors in the cleanroom must be cleaned once every 2 days (the frequency may be changed by the CCE).

5.2.3.4 TV Testing, Outgassing Measurements

Four TQCMs must be employed in the WFC3 thermal vacuum test and the GSE/Chamber pre-test vacuum outgassing certification. They must be able to maintain –20 ^{o}C and –65 ^{o}C continuously. One must be in the chamber, above the TV fixture with as much view of the entire contents of the chamber as possible. Two must be mounted in the back heater panel of the TB fixture, each viewing a vent: an optics cavity vent and an electronics cavity vent. The fourth must be mounted to the front of the thermal balance fixture, viewing the front aperture of the instrument without blocking the view between the stimulus and the instrument aperture. The TQCMs must be positioned whenever makes sense in the set-up activities flow.

All of the equipment used in the WFC3 thermal vacuum testing must be loaded into the chamber for a pre-test certification. The pre-test certification provides the chamber and GSE outgassing background so that an accurate determination of the outgassing of the WFC3 can be made. The pre-test outgassing certification test also verifies that the GSE will not contaminate the WFC3 during the TV instrument test. All GSE must be vacuum baked at high temperatures prior to this GSE/Chamber outgassing certification and should therefore be clean. However, if any of the GSE is handled outside a clean environment after this earlier vacuum bake, it must be re-cleaned. The CCE must specify the cleaning procedure for such an occasion. Materials lists for all GSE must be provided to 545 to verify compliance with the ASTM-E-595 outgassing screening criteria (as specified in STR-29) well in advance of the final integration of the GSE. For this pre-test certification the TQCMs must read below TBD Hz/hr for 8 consecutive hours.

The WFC3 must meet the HST requirement of 1.56e-9 gm/cm^2-hr as measured on a collecting surface at –20 ^{o}C with the WFC3 at 10 ^{o}C above its maximum predicted on orbit temperature, or in hot operation mode. The TQCM criteria equivalent to that outgassing rate must be provided by code 545 after the geometry of the test set-up is finalized. A scavenger plate must be flooded with LN_2 for the duration of the test, behind the stimulus to collect any contamination vented out the back of the GSE. An eight hour cold finger must be activated after all the testing is complete.

5.2.4 EMI Facility

The Large EMI Test Facility (LETF) is a horizontal flow cleanroom.

5.2.4.1 Environment

The LETF must be operated as a class 10,000 cleanroom and must be monitored per NSI 35-01-205. Studies have shown that the room maintains the following characteristics:

- NVR accumulation of approximately 0.2 mg/ft^2 in 3 months
- Particulate fallout less than Level 400/week
- Airborne hydrocarbons less than 5 ppm

If routine monitoring indicates higher levels of contamination, the HST CCE must be notified, even if the cleanroom operating limits are not exceeded. Monitoring must be performed in accordance with Table 6-1 of the WFC3 CCIP. Cable feedthroughs in the wall of the facility must be closed out with bagging material.

5.2.4.2 Handling

After arrival in the LETF cleanroom, the entry door must be closed and the room allowed to settle for 30 minutes prior to removal of the WFC3 inner bag. A maximum of 8 people are permitted in the LETF when WFC3 is not draped with bagging material. ESD wrist straps are required by all personnel in the control area. Tape cuff sealers are not permitted due to ESD constraints. Overnight and when operations permit, the WFC3 must be draped with Lumalloy. The WFC3 must be continuously purged using an HST purge cart. Prior to leaving the LETF, the WFC3 must be double bagged.

5.2.4.3 Monitoring

After unbagging in the LETF cleanroom, two optical witness mirrors must be deployed in the WFC3 area. Two of the WFC3 traveling mirrors must be exchanged for new mirrors. One particle fallout plate must be placed downstream of WFC3. A white light inspection must be performed to verify that WFC3 is VCHS.

The fallout plate must be exchanged and measured weekly. After bagging the WFC3 for transport to another facility, the two LETF mirrors must be measured.

5.2.5 Acoustics Facility

5.2.5.1 Environment

The WFC3 will be installed in the Radial Scientific Instrument Protective Enclosure (SIPE) for the acoustics test. Prior to installation into the SIPE, the SIPE interior must be tapelift sampled in three places and NVR swab sampled in two places. Cleanliness must be at least level 400A. The SIPE must also be cleaned and VCHS+UV.

5.2.5.2 Handling

The WFC3 must be installed and removed from the SIPE in a class 10,000 cleanroom. The SIPE must be continuously purged during acoustics testing, and have the vent flow restrictor in place. Under these conditions, the SIPE will maintain the cleanliness of WFC3.

5.2.5.3 Monitoring

Prior to transportation out of the cleanroom, one SIPE witness mirror must be changed out. After returning to the cleanroom, the SIPE witness mirror must be changed out again. After removal from the SIPE, WFC3 must be inspected to VCHS. If the SIPE witness mirror shows more than 1% degradation, the WFC3 must be rinse sampled for NVR.

5.2.6 Mass Properties Facility

The mass properties and modal survey facilities are not environmentally controlled.

5.2.6.1 Environment

If vibration or modal testing is required, the WFC3 must be bagged or in a cleantent certified to class 10,000.

5.2.6.2 Handling

The WFC3 must be double bagged after instrumentation and while in a class 10,000 environment. Instrument leads must be brought out of the bag at a common point. The WFC3 must be continuously purged during the test, unless this will interfere with the measurement. If the purge must be discontinued, airborne hydrocarbons must be verified to be less than 15 ppm before disconnecting the purge.

5.2.6.3 Monitoring

If the WFC3 is bagged, no monitoring of the facility is required. If a cleantent is used, the tent must be monitored per Table 6-1 of this document.

5.2.7 Detector Characterization Lab

The detectors will be tested in the Detector Characterization Laboratory at GSFC. This facility has been specifically designed to be a cleanroom and a light tight detector lab. NSI contamination is responsible for cleaning and monitoring both particles and NVR in this facility.

5.2.7.1 Environment

The lab is a class 10,000 cleanroom. This room must be certified and monitored per section 6 of the WFC3 CCIP for a minimum of 30 days prior to the arrival of the WFC3 detectors. All equipment in the tent must be cleaned to VCHS + UV. Areas of the bench setup which are difficult to clean may be bagged or tapped off. All equipment and garments used in the DCL will be approved for use in a Class 10,000 cleanroom. Conduct in the DCL will be consistent with conduct approved for a Class 10k cleanroom.

5.2.7.2 Handling

After the detector outer bags are removed, the detectors must be moved into the nitrogen purge box. The detector shall only be unbagged while on a class 100 laminar flow bench. The detector purge may be discontinued during the characterization test. As soon as testing is complete, the detectors must be double bagged and purged.

5.2.7.3 Monitoring

The DCL must be monitored per section 6 of the WFC3 CCIP.

5.2.8 Systems Lab for Alignment and Calibration (SLAC)

The Stimulus, RIAF, and all associated ground equipment needed for optical alignment of WFC3 will be stored and tested in the SLAC.

All components and equipment will be cleaned to visibly clean highly sensitive plus UV and bagged for delivery to the SSDIF where the precision cleaning will be done in the Precision Cleaning Room. The precision cleaned components and equipment will then be transported into the SSDIF.

5.2.8.1 Environment

The SLAC is a good housekeeping area. If the Stimulus, RIAF, and other optical alignment fixtures must be used under cleanroom conditions and cannot be used in the SSDID, a Clean Tent [Class 10k or less] will be constructed inside the SLAC for such use.

5.2.9 Room 150

Some integration activities may take place in Building 29, Room 150. This room will have a horizontal flow, Class 10,000 clean tent installed prior to use by WFC3.

5.2.9.1 Environment

The flight hardware will only be exposed inside a Class 10,000 clean tent. This tent must be certified and monitored per section 6 of the

WFC3 CCIP for a minimum of 60 days prior to the arrival of the WFC3. All equipment in the tent must be cleaned to Level 400A or better. Areas of the optical setup which are difficult to clean may be bagged or tapped off. Conduct in the tent will be consistent with conduct approved for a Class 10k cleanroom.

The nominal ambient parameters for this tent shall be:

Flow rate >= 100 feet per minute

Humidity = 44% +/-4%

Temperature = 68 ^{o}F +/- 2 ^{o}F

5.2.9.2 Handling

After arrival in the Room 150 clean tent, the roll up “door” must be closed, and the tent must be allowed to settle for 30 minutes prior to removal of the WFC3 inner bag. A maximum of 6 people are permitted upstream of the WFC3 when WFC3 is not draped with bagging material. ESD wrist straps are required by all personnel in the control area. Tape cuff sealers are not permitted due to ESD constraints. Overnight and when operations permit, the WFC3 must be draped with Lumalloy. The WFC3 must be continuously purged using an HST purge cart. WFC3 must be draped before beginning any crane operations. Prior to leaving the SSDIF, the WFC3 must be double bagged.

5.2.9.3 Monitoring

After unbagging in the clean tent, two optical witness mirrors must be exposed. Two of the WFC3 traveling mirrors must be exchanged for new mirrors. One particle fallout plate must be placed immediately downstream of WFC3. A white light inspection must be performed to verify that WFC3 is Visibly Clean Highly Sensitive. If the optical witness mirrors which traveled with WFC3 show more than 1% degradation, the CCE may require an NVR rinse to be performed on WFC3.

The fallout plate must be exchanged and measured weekly. After bagging the WFC3 for transport to another facility, the two exposed mirrors must be measured.

5.2.10 Other Test Facilities

When the WFC3 must be tested outside a cleanroom environment the flight hardware must be double bagged with Lumalloy.

5.3 KSC

5.3.1 Post-Ship checkout (Hangar AE)

Hangar AE is a class 10,000 cleanroom. If a different cleanroom is used for WFC3 post-shipment checkout, these requirements must apply to that facility.

5.3.1.1 Environment

Post shipment checkout must occur in a class 10,000 cleanroom. The cleanroom must be monitored in accordance with Table 6-1 of this document. Monitoring must commence at least 30 days prior to WFC3 arrival.

5.3.1.2 Handling

After arrival in the airlock, the airlock doors must be closed and the room allowed to settle for 30 minutes. Personnel entering the airlock after the door is closed must be wearing cleanroom attire. The shipping container lid must be removed before the WFC3 is moved into the cleanroom. After the door to the cleanroom has been closed, the room must be allowed to settle for 30 minutes prior to removal of the outer bag.

WFC3 must be purged continuously. WFC3 must be double bagged before leaving the facility.

5.3.1.3 Monitoring

After unbagging in the cleanroom, two optical witness mirrors must be deployed in the WFC3 control area. Two of the WFC3 traveling mirrors must be exchanged for new mirrors. The removed mirrors must be measured at GSFC. One particle fallout plate must be placed immediately downstream of WFC3. WFC3 will be inspected and cleaned to VCHS+UV. If the optical witness mirrors which traveled with WFC3 show more than 1% degradation, an NVR rinse must be performed on WFC3.

The fallout plate must be exchanged and measured weekly. After bagging the WFC3 for transport to another facility, the two facility mirrors must be measured.

5.3.2 Carrier Integration (PPF)

The Payload Processing Facility will be typically operated as a class 100,000 cleanroom. For a minimum of one week prior to WFC3 shipment to the facility, the facility must be operated as a class 10,000 cleanroom.

5.3.2.1 Environment

During the week preceding WFC3 integration, the facility must be monitored by the CCE to verify that Class 10,000 cleanliness is being maintained during operations. A facility walkdown must be conducted and possible contamination sources must be removed from the cleanroom. Experience has shown that the use of air bearings increases airborne particulate levels in the vicinity of the bearing. Immediately prior to any air bearing use while the WFC3 is unbagged or a SIPE is open, the floor area which will be traversed must be damp mopped.

5.3.2.2 Handling

After arrival in the Payload Processing Facility, the Aft Shroud components must be inspected to 400B. Exterior components must be inspected to VCHS. Prior to bagging for installation in the Canister (or final MLI closeout for covered components) the WFC3 must be reinspected. WFC3 must be purged continuously. After installation in the SIPE, the SIPE must be purged continuously.

5.3.2.3 Monitoring

Real time monitoring of the particulate and hydrocarbon levels in the facility must be performed near the SIPE using portable monitors. After the SIPE is opened, and prior to post integration closure, a tapelift must be taken from the interior. The SIPE must be Level 400A or better before the WFC3 instrument may be installed. Post integration verification must be accomplished by the use of witness plates and witness mirrors. At least two particle fallout plates must be used for each SIPE integration. The plates must be placed near the SIPE opening after the SIPE is opened. These plates must be collected as soon as the SIPE is closed again. SIPE optical witness mirror changeout may occur after the integration is complete.

5.3.2.4 Personnel Constraints

Only those persons required for the integration must be permitted in the cleanroom while the WFC3 or SIPE interiors are exposed. Personnel within the cleanroom must remain as far from the open SIPE as practical for their activity. Persons near the SIPE must minimize unnecessary movement and activity. As a goal, no more than 13 people must be permitted in the cleanroom during the integration.

5.3.2 Vertical Processing Facility (VPF)

The WFC3 will not be exposed in the VPF. The SIPE must be continuously purged.

5.3.3 Payload Changeout Room (PCR)

The WFC3 will not be exposed in the PCR. The SIPE must be continuously purged.

5.4 ORBIT

5.4.1 EVA

To minimize polymerization of contamination on the WFC3 optics, the Orbiter must be in a sun-avoidance attitude during WFC3 changeout. To reduce exposure to silicones and atomic oxygen, EVA operations shall be practiced to keep the WFC3 aperture and pickoff mirror pointed away from the ram direction. If these constraints are followed, and because the instrument will be warmer than the shuttle payload bay, minimal contamination is expected during translation of the instrument to HST.

WFC3 has a large open aperture which must be protected from debris in the vicinity of HST. The EVA sequence of operations can impact the particulate contamination probability; operations such as exterior MLI changeout should be scheduled later than the WFC3 changeout. If a particle cloud is generated prior to WFC3 changeout, the contamination engineering team must be consulted as to whether an orbit altitude change is required prior to performing WFC3 changeout.

5.4.2 SMOV

For a period of no less than 4 weeks following installation into HST, the desorption of surface contaminants, combined with exposure to UV light, poses a risk to the optics. During this period, HST must not view the illuminated earth (bright earth avoidance).

6.0 CLEANROOM OPERATIONS

To efficiently operate cleanroom facilities while allowing the maximum number of personnel to be present, certain operational requirements must be met. These requirements are outlined in Table 6-1. The establishment of the maximum number of operating personnel must be a function of the cleanroom requirements and empirical fallout and air sampling results within the facility. QA and the CCE must assist in this personnel determination. When a temporary increase in personnel is necessary, a procedure must be implemented (temporary procedures must be verified by QA). In order to meet the operational requirements, the following measurement equipment may be needed:

- · A particle counter
- · A Total Hydrocarbon Analyzer (THA)
- · An Image Analyzer
- · Temperature, relative humidity (RH), and air velocity monitors
- · Sampling support hardware

6.1 CLEANROOM RECERTIFICATION

The cleanroom facilities must be recertified if the following conditions occur.

- If the particle count, temperature, or humidity as measured by the continuous chart recorder in the cleanroom exceeds the requirements specified in Table 6-1 for more than 30 minutes, all work must cease in the facility. The facility operator must determine when work may proceed. At least two readings must be recorded in every eight hour shift.

- If any other monitoring specified in the Table 2 does not meet the specifications, all work must cease until the problem is corrected and verified by QA.

- Any structural changes to the room must require a recertification.

- Any filter removal or changeout must require a recertification.
- Any scheduled and approved maintenance to the air condition system/mechanical system occurs.

All hardware must remain bagged and all tests and assembly must be suspended when the facility does not meet specifications or is being recertified.

6.2 GENERAL ADMISSION REQUIREMENTS

Personnel are the greatest potential source of both particulate and molecular contamination. In order to control this source, garment requirements, proper training of personnel, and facility constraints must be established and be monitored by QA.

Table 6-1: Operational Requirements

Environmental Constraint	Class 10,000	Class 100,000	Monitoring Method
Maximum airborne particulate counts per cubic foot Particles > 0.5 micron Particles > 5.0 micron	 10,000 70	 100,000 700	Continuous chart recording
Temperature (°F)	68-72	68-72	Continuous chart recording or QA approved system
Relative Humidity (%)	40-55	40-55	Continuous chart recording or QA approved system
Maximum particle fallout per MIL-STD-1246 averaged over a 7 day period	Level 400	Level 750	Weekly samples exposed for one week each
Maximum NVR fallout averaged over a one month period	<3% at 0.1216 mm on a witness mirror	< 2.0 mg/ft^2	NVR rinse plate
Maximum total hydrocarbons (methane equivalent)	15 ppm	N/A	Continuous chart recording via THA

Minimum positive pressure	0.1 inch H_2O	0.05 inch H_2O	weekly
Minimum air flow	90 FPM	80 FPM	daily

6.2.1 Garment Requirements

Proper selection of cleanroom garments is essential to the operation and maintenance of a cleanroom. Class 10,000 cleanroom attire must consist of a coverall (bunny suit), hood, booties, facial masks, and Class 100 nitrile or latex gloves. Class 100,000 cleanroom attire must consist of a frock, bouffant cap, booties, and latex or nitrile gloves. Solvent resistant gloves must be worn when solvents are used. Electro Static Discharge (ESD) wrist straps must be pretested and worn (in contact with bare skin) when working with static sensitive hardware.

6.2.2 Authorized (Trained) Cleanroom Personnel

All personnel assigned to perform work on the WFC3 in a clean area must be properly indoctrinated and trained in cleanroom procedures. The indoctrination and training must include proper dressing procedures, proper entrance/exit to the cleanroom, ESD certification, and proper personnel behavior.

QA must monitor that personnel have been properly trained. An authorized access list to the cleanroom must be posted near the entrance to the cleanroom as necessary for personnel control. If one time access is required by a person who is not certified, that person must be escorted by QA or the CCE.

Personnel are responsible for personal constraints while working in the facility. The following is a condensed list of prohibited activities for a Class 10,000 or Class 100,000 cleanroom.

- Cosmetics, after-shave and perfume must be avoided.
- Personnel with severe colds (causing coughing and/or sneezing), skin or respiratory problems, or using external medications are excluded. Any questions should be directed to QA or the CCE.

- No food or drink are allowed in the cleanroom. This includes candies.
- If personnel smoke prior to entering the cleanroom, they must wait 15 minutes and drink some water before entering the cleanroom.
- Touching of skin, uncovering of hair, or removal of items from garment pockets while in the cleanroom is prohibited.

Any questions about the above requirements or any non-listed constraints should be directed to QA or the CCE. Violation of any of the above requirements should be immediately brought to the attention of QA and the CCE.

6.2.3 Facility Constraints

Facility constraints also play an important role in sustaining cleanroom requirements. They include operational requirements, maximum personnel, introduction of items in/out of the cleanroom, GSE equipment, crane maintenance, and good housekeeping procedures (cleanroom maintenance).

6.2.3.1 Operational Requirements

- Report all visible contamination on hardware and work surfaces to QA or the CCE.
- Avoid abrasive materials, unapproved packaging material, Kimwipes, paper core tapes, masking tape, felt-lined cases, files, drills, saws, pencils, erasers, crayons, chalk, non-cleanroom paper, and manuals. Avoid vinyl films, RCAS 2400, neoprene, etc. If any items are of concern, contact the CCE or QA.
- Since the floor is considered the most contaminated surface in the cleanroom, any flight hardware that touches the floor must be recleaned.
- When drilling, filing, or soldering is required in the cleanroom, prior approval must be obtained from QA, the CCE, and the hardware manager. Supervision must be performed by QA and the CCE. A HEPA filtered vacuum cleaner must be utilized to capture small particulates, and a collector bag used to capture heavy particulates.

- Avoid, if possible, working over exposed flight hardware or between the filters and the hardware, especially when optics are exposed. Proper procedures must be implemented by QA.
- Sealing of bags by heat is discouraged due to material outgassing. Taping with an approved material is preferred.
- Clean refuse containers must be provided for use within the cleanroom for excess debris and to reduce entrance/exit traffic.

6.2.3.2 Maximum Personnel

The maximum number of personnel allowed in the clean area must be posted outside the cleanroom or work area. If the maximum number must be temporarily increased, correct procedures must be verified by the CCE and QA to ensure the facility remains within operating specifications.

6.2.3.3 Items Entering/Exiting the Cleanroom

- All hardware not prepackaged must be inspected and, if necessary, cleaned before entering the controlled area. The items must be inspected by QA. All pre-cleaned items must be double bagged and have verification papers presented to QA or CCE prior to entering the cleanroom.
- All support items that are uncleanable or difficult to clean can be used in a bagged configuration. The outside of the bag must be inspected and verified as clean by QA/CCE.
- Small tools and hand-carried support equipment must be cleaned prior to entrance with monitoring by QA.
- Correct procedures for using pass through windows or benches must be implemented. Procedures must be monitored by QA or the CCE.
- Large items moved into the cleanroom must be scheduled and procedures must be reviewed prior to entrance by QA and the CCE.
- If an item exits the cleanroom, the bag used to bring the item into the cleanroom must be used to remove the item from the cleanroom. The CCE must designate the area to store such bags within the cleanroom and implement procedures prior to exit.

6.2.3.4 Ground Support Equipment

The GSE consists of Mechanical Ground Support Equipment (MGSE) and Electrical Ground Support Equipment (EGSE). The MGSE covers items such as: work platforms, dollies, lifting devices, air pads, module installation equipment, specialized tools, slings, and fixtures. The EGSE includes the computers and electronics racks. All GSE must be wiped down prior to entry using compatible and approved solvents to attain VCHS exterior surfaces. Some GSE (especially optical elements, such as theodolites) may have more stringent requirements imposed by the CCE or the responsible engineer. Inspection and approval of GSE must be the responsibility of QA and the CCE.

6.2.3.5 Crane Maintenance

During crane maintenance, all WFC3 hardware must be bagged or covered. If bagging or covering is not possible, a debris shield must be used. This shield must be located above the hook and below the pulleys. The crane must use only low outgassing lubricants for moving parts.

Where applicable, the bridge area that the crane travels along (both x and y) must be cleaned once annually to a visibly clean standard level.

6.2.3.6 Cleanroom Maintenance

Cleanroom maintenance must include the following.

- Establishment of a routine cleaning procedure for daily trash removal and for weekly floor cleaning to sustain required levels.
- Covering of all sensitive hardware during cleaning of the room.
- Cleaning equipment must be cleaned to the same cleanliness level as hardware brought into the cleanroom.
- All cleaning materials must be cleanroom compatible (low outgassing and low particle shedding).

ACRONYMS

ASM	Aft Shroud Mockup
BALL	Ball Aerospace
CCD	Charge Coupled Device
CCE	Contamination Control Engineer
CCIP	Contamination Control Implementation Plan
CEB	CCD Electronics Box
CQCM	Cryogenic Quartz Crystal Microbalance
DEB	IR Detector Electronics Box
EMI/EMC	Electromagnetic Interference/ Electromagnetic Compatibility
ESM	Electronics Support Module
GSE	Ground Support Equipment
GN_2	Gaseous Nitrogen
GSFC	Goddard Space Flight Center
HEPA	High Efficiency Particulate Air
HFMS	High Fidelity Mechanical Simulator
HST	Hubble Space Telescope
IR	Infrared
IPA	Isopropyl Alcohol
KSC	Kennedy Space Center
LETF	Large EMI Test Facility
LN_2	Liquid Nitrogen
LVPS	Low Voltage Power Supply
MEB	Main Electronics Board
MLI	Multi Layer Insulation
MULE	Multi Use Light Equipment

MPPF	Multi-Payload Processing Facility
NCC	NICMOS Cryo Cooler
NICMOS	Near Infrared Camera / Multi Object Spectrograph
NVR	Non-volatile Residue
OB	Optical Bench
ORU	Orbital Replacement Unit
ORUC	Orbital Replacement Unit Carrier
PCR	Payload Changeout Room
PPF	Payload Processing Facility
ppm	Parts Per Million
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
RIAF	Radial Instrument Alignment Fixture
RH	Relative Humidity
SAW	Surface Acoustic Wave
SBC	Solar Blind Channel
SCFH	Standard Cubic Feet per Hour
SES	Space Environment Simulation
SIPE	Scientific Instrument Protective Enclosure
SISS	Science Instrument Support Structure
SSDIF	Spacecraft Systems Development and Integration Facility
SWALES	Swales Aerospace
TA	Turbo Alternator
TB	Thermal Balance
TBD	To Be Determined
THA	Total Hydrocarbon Analyzer
THC	Total Hydrocarbons
TQCM	Temperature Controlled Quartz Crystal Microbalance
TV	Thermal Vacuum
UV	Ultraviolet

UVIS	Ultraviolet/Visible (channel)
VCHS	Visibly Clean Highly Sensitive
VEST	Vehicle Electronics Simulation Test facility
VPF	Vertical Processing Facility
WFC3	Wide Field Camera 3
WF/PC	Wide Field / Planetary Camera

APPENDIX A: OPTICAL BENCH FABRICATION

The following controls shall be observed during optical bench panel fabrication:

Supplies:

- Only use WFC3 approved (and marked) materials
- Do not store WFC3 materials or equipment outside the control area
- Remove cuttings / left over paper / misc. stuff before leaving area
- Clean any tools / supplies as they are brought into the area (scissors, pens, tape dispensers)

Garments:

- Make sure hair is fully covered
- Don a fresh pair of gloves each time you enter the WFC3 area
- Use polyethylene gloves (over the nitrile) when using solvents for more than 15 minutes
- Frock, gloves, and hair net are required for all, beard cover for facial hair

Access:

- WFC3 control area shall be designated with stanchions and chains
- No VIP visitors in the control area
- Minimize time that doors are open (especially to the mold release storage area)

WORK PROCEDURES:

- Cover the hardware when not being worked on for more than 1 hour
- After leaving the oven and returning to the work area, minimize the time until completion of work (so don’t start something that will be left over the weekend!)
- Clean both the bonding and outside surfaces of the panels
- Bag (tape seal) the panels when completed

The following materials are approved for use during optical bench panel fabrication:

Material	Supplied By	Stored at
Chemsoft CE Nitrile Gloves	WFC3	OB Work Area
Polyethylene Gloves	WFC3	OB Work Area
IPA, HPLC Grade	WFC3	OB Work Area, excess in Bonded, Flammable Storage
Acetone, HPLC Grade	WFC3	OB Work Area, excess in Bonded, Flammable Storage
MEK	WFC3	OB Work Area, excess in Bonded, Flammable Storage
Simple Green (Clear)	WFC3	OB Work Area
Llumalloy	WFC3	OB Work Area
Teflon Peel Ply	Manufacturing (WFC3 Task)	OB Work Area
Kraft Paper	Manufacturing (WFC3 Task)	OB Work Area
ULO Polyethylene Film / Bags	WFC3	OB Work Area
Deionized Water	WFC3	OB Work Area
Solvent Bottles	WFC3	OB Work Area
Signs	WFC3	OB Work Area
Chains and Stanchions	Manufacturing	OB Work Area
Storage Bins	WFC3	OB Work Area
Kapton Tape (Acrylic Adhesive)	WFC3	OB Work Area
Process Adhesives	Manufacturing (WFC3 Task)	SSS Adhesive Storage
Scotchbrite Pads	Manufacturing (WFC3 Task)	OB Work Area
Alpha 10 Cleanroom Wipes	WFC3	OB Work Area
Cart for Peel Ply, Kraft Paper, Llumalloy, and Polyethylene	Manufacturing	OB Work Area